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Direct Current Resistivity
Geophysical Investigation of Buried
Metal-Bearing Sludge Ponds,
Litton Industries Facility,
Springfield, Greene County, Missouri.

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Direct Current Resistivity Geophysical Investigation of Buried Metal-Bearing Sludge Ponds Litton Advanced Circuitry Division (ACD), Springfield, Greene County, Missouri.

1.0 INTRODUCTION

This report presents the results of a direct current electrical resistivity survey conducted at the Litton Advanced Circuitry Division (ACD) facility, Springfield, Greene County, Missouri (Figure 1). The general requirements for this study were established during discussions with Mr. Arthur J. (Chuck) Gordon, CPG, Project Manager for SCS Engineers and Kenneth M. Euge, R.G. of Geological Consultants during July 1990. The scope of services is defined in Geological Consultants Proposal for Services dated August 3, 1990 (revised November 16, 1990). The work was performed under an agreement between Geological Consultants and SCS Engineers dated November 16, 1990.

The purpose of this investigation is to obtain resistivity data that can be used to identify low resistivity targets at the Litton ACD site. Targets include the suspected locations of the "New" Acid Pit and the Former Sludge Pit. The targets reportedly contain high concentrations of copper and other metals found in soil sampled by SCS Engineers (1990). Presence of metals in the site soils has resulted from past practices of on-site disposal of industrial processing wastes. In addition to identifying the limits of the disposal areas, other potential targets are defined for consideration of future evaluation.

The surface geophysical methods used to measure in-place apparent electrical resistivity includes the following direct current (d.c.) methods:

1) Vertical electrical soundings (VES) using the Schlumberger electrode array (Figure 2) can quantitatively determine subsurface layering (bedding thicknesses and intrinsic resistivity). A layer can be distinguished by this method if it represents a resistivity contrast between adjacent layers.

2) Horizontal electrical profiling with the Wenner electrode array (Figure 3) can be used to detect subsurface resistivity changes in a horizontal direction. Apparent resistivity values are contoured to identify lateral variations of abnormally high and low resistivity areas.

Field work at the Litton ACD site was performed by Geological Consultants between December 17 and 21, 1990.

2.0 ELECTRICAL RESISTIVITY SURVEY METHODOLOGY

2.1 Instrumentation

Apparent resistivity measurements can be made by causing a known current (I) to flow between two outer electrodes (steel rods) in contact with the ground. This current establishes an electrical field in the earth with the distribution depending on the resistivities and thicknesses of the subsurface materials. The electrical field was determined by measuring the potential difference, (ΔV), between two inner surface electrodes (steel rods). The system instrumentation employed during this study was a Bison Model 2350B resistivity meter. The system sensitivity is about 3 ohm-feet (1 ohm-meter).

2.2 Vertical Electrical Soundings (VES)

In vertical electrical soundings, the separation (L) between the current electrodes is increased along a straight line. The inner electrode separation (MN) remains fixed at the array center. As the array expands, the electrical field at greater depths produces a larger influence on the surface measurements. Therefore, the effective exploration depth increases as the current electrode separation increases. By expanding the array and making several measurements, it is possible to construct an apparent resistivity sounding curve to interpret the number of subsurface layers, their thicknesses and intrinsic resistivity values. Such interpretations are non-unique, but the interpretations can be constrained by either site geological information or subsurface exploration data.

2.2.1 Data Acquisition

The locations of the VES are shown in Figure 2. Soundings BS-1a and BS-1b were performed to develop a background resistivity geoelectric earth model. The area is reportedly unaffected by waste disposal. Soundings SPS-1a and SPS-1b are centered at monitor well MW-7 where high metal concentrations have been reported.

About 15 measurements were made for each sounding, with the current electrode separation (L) expanding progressively from 3 feet to 300 feet. Using a maximum L-spacing of 300 feet, the effective penetration depth for this survey should be greater than 75 feet (Roy and Apparao, 1971). Data were reduced and plotted in the field to provide a check on data quality.

2.2.2 Data Reduction

Apparent resistivity values were calculated from the observed data using the following equation for the Schlumberger electrode array geometry:

$$Pa = 2\pi (V/I)(MN/2)\left[(L^2/MN) - .25\right] \text{ ohm-feet.}$$

To obtain apparent resistivity values in ohm-meters, multiply ohm-feet values by 0.3048.

Sounding curves were constructed using apparent resistivity verses L-spacing plotted on 3-cycle log-log grid paper. The resistivity sounding data were interpreted with an inverse and forward modeling program, RESIXP (Interpex Limited, 1988). Forward modeling permits the calculation of a synthetic resistivity sounding curve for an earth model with several layers (Davis, et al; 1980). Once the best estimate of the model compares favorably with the observed data, inverse modeling is performed. The resulting inverse model is developed from a least squares analysis of the data. This is accomplished using ridge regression analysis (Inman, 1975) to adjust the parameters of the starting geoelectric model. The final model was obtained by constraining some of the starting parameters based on knowledge of the soils and bedrock stratification characterized in site borings logs (SCS Engineers, 1990).

2.3 Horizontal Electrical Profiling

In horizontal resistivity profiling, the Wenner electrode array is used at different locations while maintaining a fixed electrode spacing. Horizontal profiling means moving a fixed array at regular intervals along parallel traverse lines. The apparent resistivity value is associated with the location of the array center. Boring logs (SCS Engineers; 1990) and the results of the VES's were used to determine the nominal spacing for the Wenner electrode array. The array spacing is selected so the effective depth of investigation envelopes the suspected low resistivity targets. Resistivity station spacings along traverse lines are selected to be smaller than the feature to be detected but the spacing can be increased based on the data obtained during the survey. The apparent resistivity values at the array centers are contoured to define the approximate lateral limits of the low resistivity targets or anomalies.

2.3.1 Data Acquisition

The areas investigated using horizontal electrical profiling techniques are depicted on Figure 2. A Wenner array current electrode a-spacing of 20 feet provides an effective investigation depth ranging between 5 feet and 10 feet below ground surface. Data were reduced and plotted in the field to provide a check on data quality.

Near the "New" Acid Pit, 75 apparent resistivity values were measured at 20-foot centers along 9 north-south oriented, parallel traverse lines (Drawing 1). Separation between traverses was 20 feet and 40 feet.

Eighty (80) apparent resistivity values were obtained in the Former Sludge Pit area. Resistivity stations were usually located on 20-foot centers. Some 40-foot center spacings were used on the east side where high resistivity values were observed (Drawing 2). Traverse lines were about 40 feet apart and oriented in an east-west direction.

2.3.2 Data Reduction

Apparent resistivity values were calculated from the observed data using the following equation for the Wenner electrode array geometry:

Pa = A [2// (V/I)] ohm-feet

Successive resistivity measurements obtained at different locations along the various traverse lines using the same electrode a-spacing should provide a weighted sampling of earth resistivity at approximately the same depth (Mooney, 1980). Individual resistivity values at the array centers are contoured by interpolation between adjacent array centers to define lines of equal apparent resistivity throughout the area investigated.

3.0 RESULTS

3.1 Vertical Electrical Soundings

Soundings BS-1a and BS-1b (Figure 5) were run in an area centered approximately 350 feet southeast from monitor well MW-7. These sounding are used to develop background geoelectric sections which can be correlated to the geological site conditions. According to Litton ACD representatives, this portion of the site was not used for waste disposal. The area is used for contract farming and cultivation of cattle feed.

The data curves show small adjustments between different MN electrode segments which implies the surrounding area is relatively laterally homogeneous. The geoelectric sections show very moist to saturated residual soils consisting of a medium resistivity silty clay or clayey silt in the upper 8 to 9 feet. Underlying the surface soil layer is a low resistivity, probably saturated, massive clay layer about 22 to 24 feet thick. The bottom of the lower clay could be easily interpreted at depths ranging from about 31 to 33 feet below ground surface where a high resistivity zone is encountered. The high resistivity zone is interpreted to represent massive limestone bedrock which is known to underlay the entire site area. The interpreted layer thicknesses and resistivities at this location are believed to have an uncertainty of about +/- 5 percent. The layered earth model in this part of the site is in general agreement with logs from subsurface exploration borings drilled at the site.

Soundings SPS-1a and SPS-1b (Figure 6) are centered at monitor well MW-7 near the Former Sludge Pit and the Former "Original" Acid Pit. The sounding location was selected in an attempt to characterize the vertical distribution of low resistivity layers that may represent accumulations of metal concentrations in the soils.

The data curves indicate the presence of moderated adjustments between the shorter electrode segments indicating the possible presence of lateral variations at shallow depths. The geoelectric sections shows a very moist, low to moderate resistivity surface layer possibly representing disturbed clayey soils 5 feet or less thick. Underlying the surface zone is a very low resistivity layer ranging from about 3 feet to 5 feet thick. This very low resistivity zone is believed to be attributed to concentrations of mobile metal ions in the very moist soil. A low resistivity layer, similar in character to the clay layer identified at sounding BS-1, extends from the base of the very low resistivity layer to a depth of about 27 feet below ground surface. A very high resistivity zone, interpreted to represent massive limestone, underlies the clay. The interpreted layer thicknesses and resistivities at this site are believed to have an uncertainty of about +/- 9 percent.

The layered earth model in this area appears to be consistent with the site geoelectric model where massive limestone bedrock is encountered about 30 feet below ground surface. However, the near surface zone appears to be significantly affected by lateral variations in apparent resistivity.

No vertical electrical soundings were performed at the "New" Acid Pit area due to the close proximity of the Litton ACD facility. Site structures that could influence VES resistivity readings include the large asphaltic concrete paved areas, chain link fences, existing disposal ponds, and buried piping. Spontaneous potentials in the earth may be generated by galvanic phenomena around electrochemically active materials or provide short-circuit paths for the current.

3.2 Horizontal Electrical Profiling

Resistivity profiling near the "New" Acid Pit shows a significant variation in observed apparent resistivities ranging from a low of 33 ohm-feet (10 ohm-meters) to a high of 208 ohm-feet (63 ohm-meters). Variations are probably attributed to the near surface lateral changes in the shallow geoelectric materials. A concentration (Area A) of very low resistivity values appear to define a rectangular area interpreted to represent the configuration and location of the "New" Acid Pit (Drawing 1). The very low resistivity values extend northward from the suspected pit site towards an area described as the Former Percolation Pond (Area B.

Variations in observed apparent resistivities are also found near the Former Sludge Pit. Values range from a low of 28 ohm-feet (9 ohm-meters) near monitor well MW-7 to a high of 261 ohm- feet (80 ohm-meters). Several very low resistivity targets are defined by resistivity contour mapping in the area (Drawing 2). A rectangular target (Area A), approximately 50 feet by 100 feet in size, is centered about 150 feet southwest of monitor well MW-7. Area A is interpreted to represent the Former Sludge Pit site. Another target (Area B), 50 feet by 80 feet in size, adjacent to the suspected Sludge Pit is also rectangular. Area B exhibits a similar range of very low resistivity. This target may be related to the Sludge Pit.

A broad, very low resistivity area (Area C) near monitor well MW-7 includes some of the lowest observed apparent resistivity values measured at the Litton ACD site. The Former "Original" Acid Pit disposal site is reportedly located in the same general area (SCS Engineers; 1990).

4.0 CONCLUSIONS AND RECOMMENDATIONS

Direct Current electrical resistivity surveys appear to have successfully identified the approximate locations of the "New" Acid Pit and Former Sludge Pit disposal sites at the Litton ACD facility. Low apparent resistivity anomalies are found southwest of monitor well MW-7 and adjacent to the northeast side of the paved parking area. The anomalies are interpreted to be attributed to high concentrations of metallic ions in the near surface soils where industrial processing wastes were disposed of in the past.

The limits of the "New" Acid Pit and Former Sludge Pit have been approximated by apparent resistivity contours ranging from 75 to 100 ohm-feet (23 to 30 ohm-meters) or less.

Other low resistivity targets have been identified that may be related to on-site waste disposal. The very low resistivity targets, particularly north of the "New" Acid Pit and north of monitor well MW-7 should be evaluated to determine their full extent.

5.0 RESISTIVITY SURVEY LIMITATIONS

Resistivity survey data and results presented in this report are derived from and interpreted from indirect geophysical investigative techniques employed at specific locations and, in part, from subsurface exploration data obtained at the site by others. The interpretations made at specific resistivity survey sites are believed to be reasonable based on the information available at the time of this study. Interpretations may not represent, nor are they intended to represent, subsurface conditions at other locations.

Precision of interpretations, such as layer thickness and true resistivity of layered materials, can be expected to be no better than 10 to 20 percent of the true values. The precision with which apparent resistivity measurements can be made at the surface is said to be about +/- 5 percent. Anomalies detected by resistivity methods, believed to be critical, should be verified by other methods since spurious anomalies can occur (Corps of Engineers, 1979).

6.0 REFERENCES

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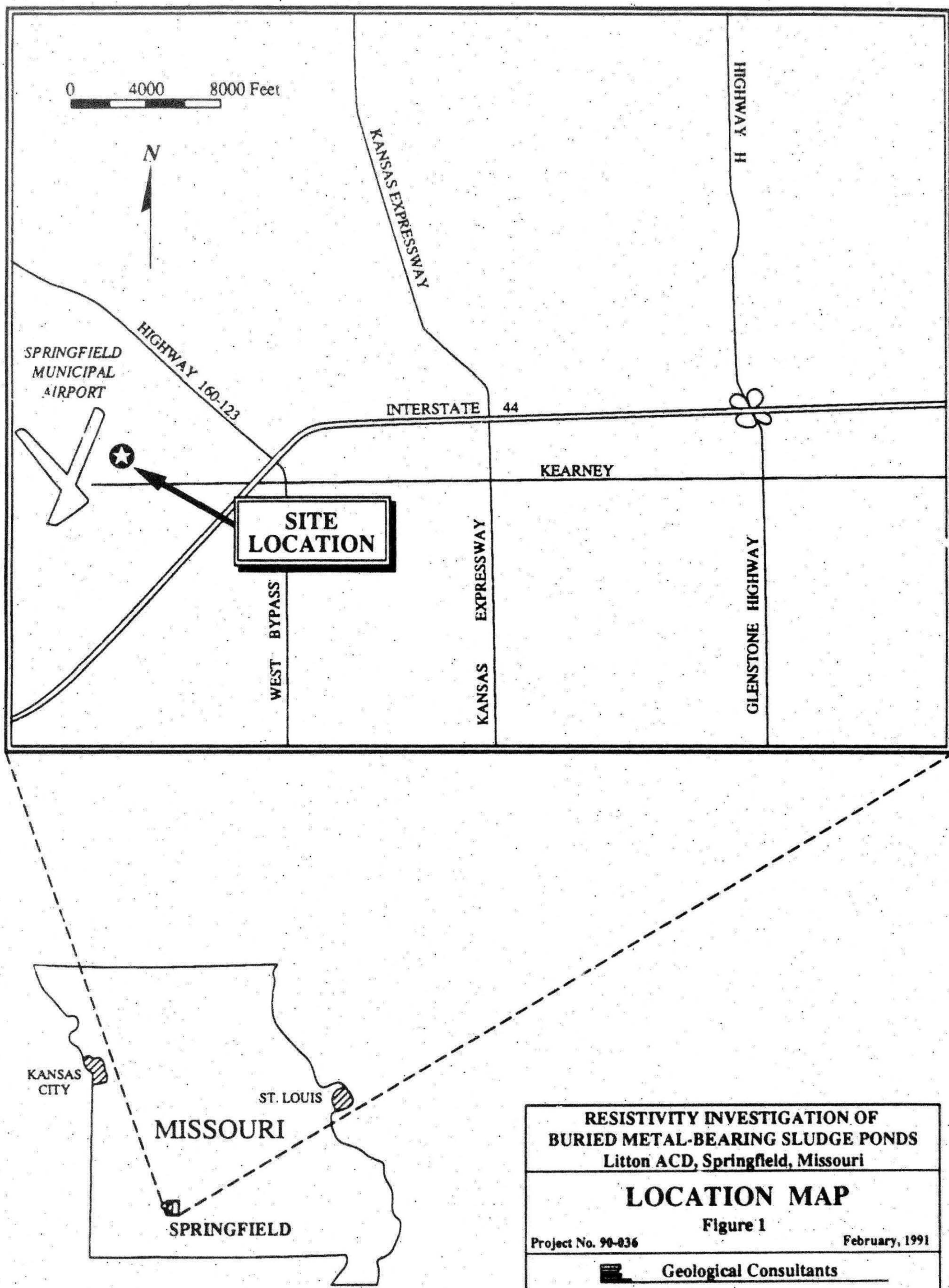

RESISTIVITY INVESTIGATION OF BURIED METAL-BEARING SLUDGE PONDS
Litton ACD, Springfield, Missouri

LOCATION MAP

Figure 1

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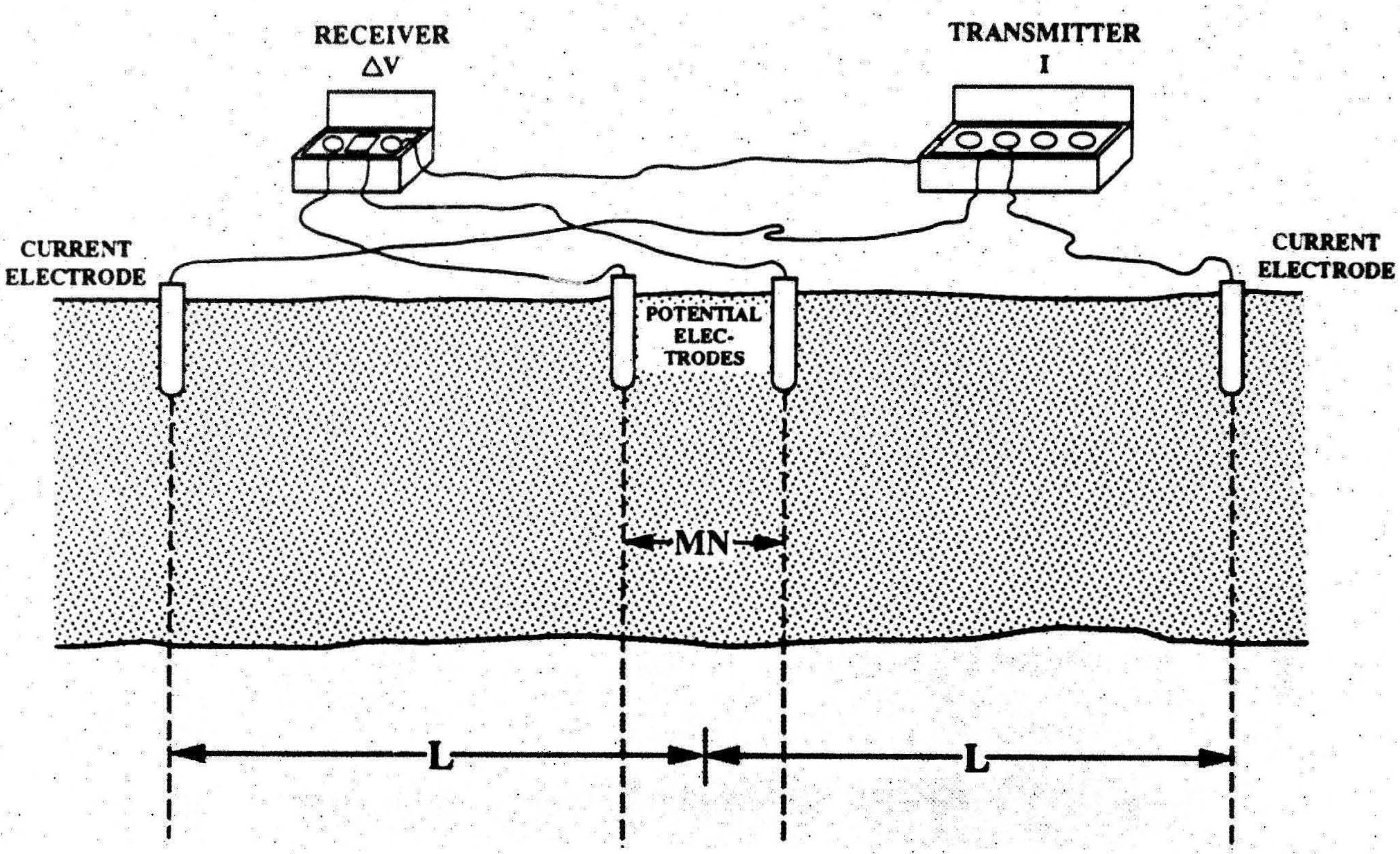

SCHLUMBERGER ARRAY
(typical)

L-spacing: current electrode spacing

MN-spacing: potential electrode spacing

RESISTIVITY INVESTIGATION OF BURIED METAL-BEARING SLUDGE PONDS
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STANDARD SCHLUMBERGER ELECTRODE ARRAY
Figure 3

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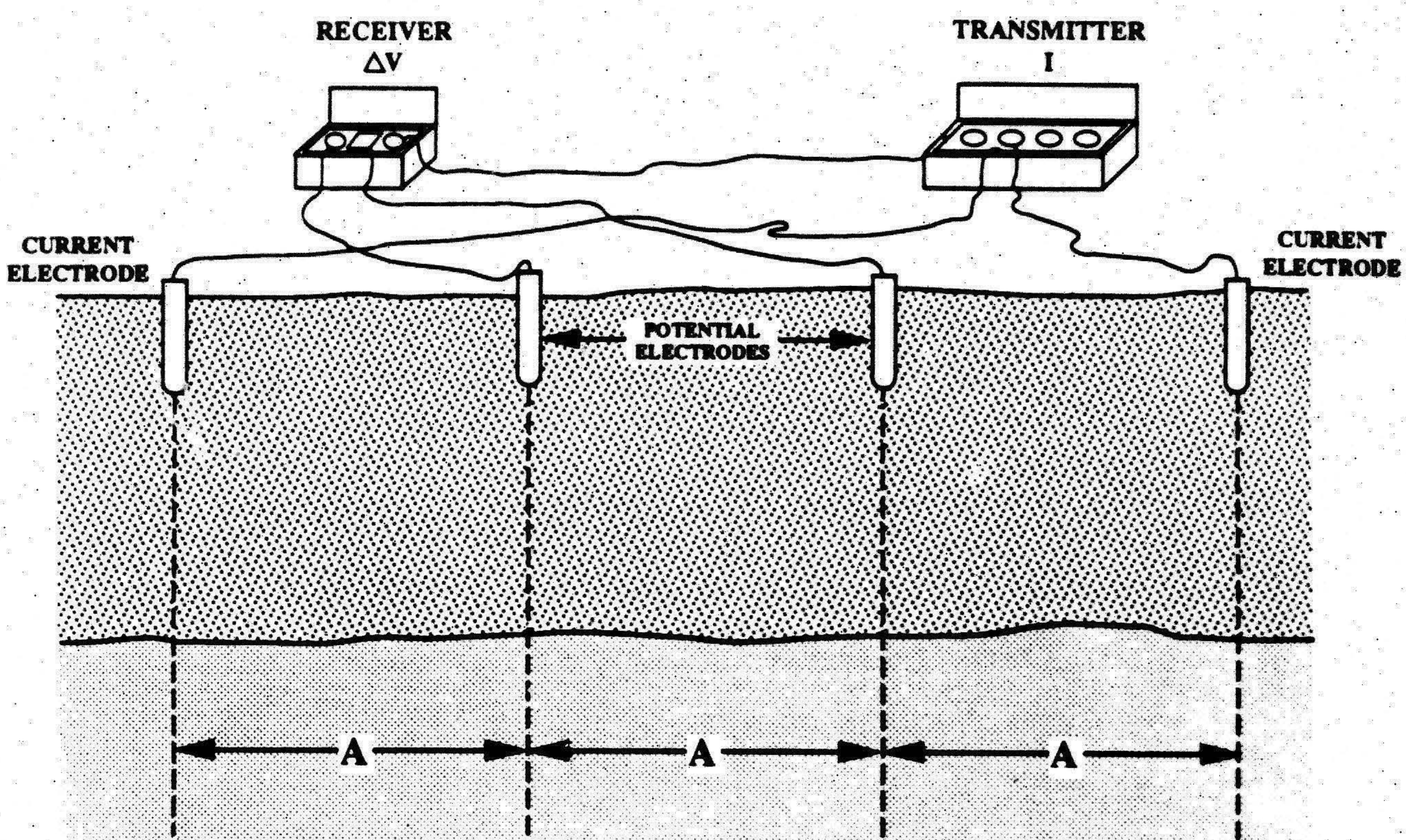

WENNER ARRAY
(typical)

RESISTIVITY INVESTIGATION OF BURIED METAL-BEARING SLUDGE PONDS **Litton ACD, Springfield, Missouri**
STANDARD WENNER ELECTRODE ARRAY **Figure 4**
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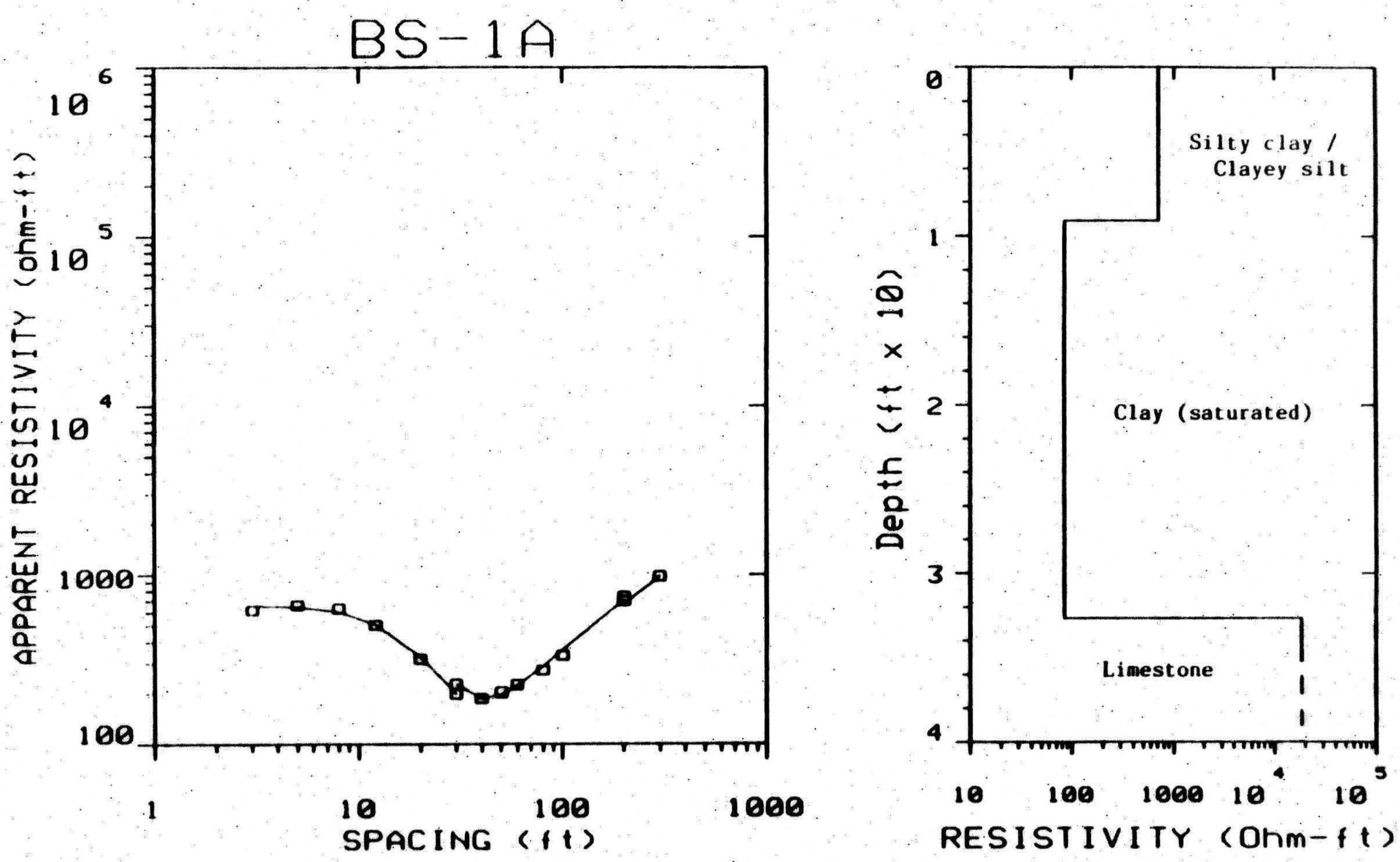

RESISTIVITY INVESTIGATION OF
BURIED METAL-BEARING SLUDGE PONDS
Litton ACD, Springfield, Missouri

VERTICAL ELECTRICAL SOUNDING
MODEL BS-1 • SOUNDING BS-1a
Figure 5a

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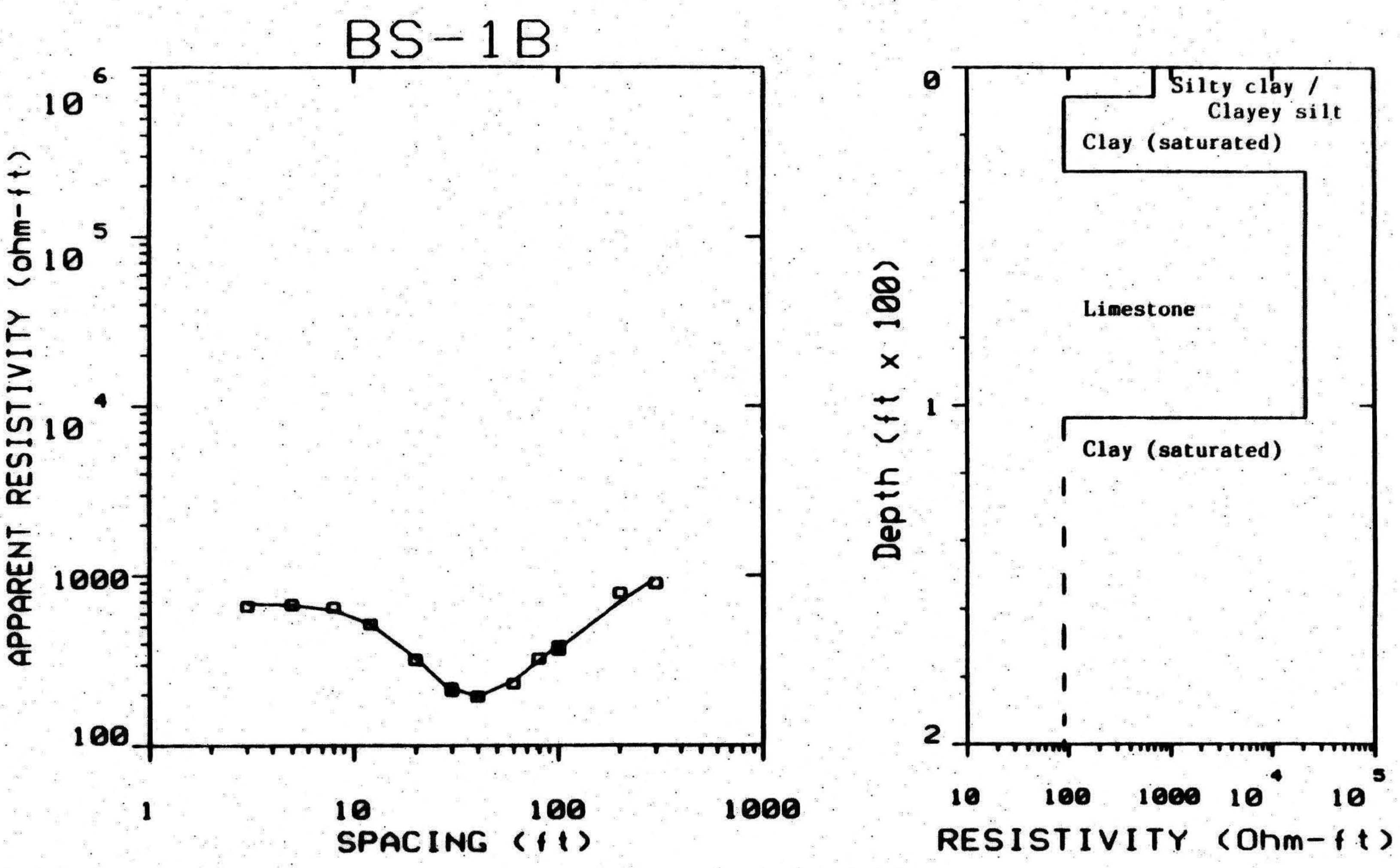

RESISTIVITY INVESTIGATION OF BURIED METAL-BEARING SLUDGE PONDS
Litton ACD, Springfield, Missouri

VERTICAL ELECTRICAL SOUNDING
MODEL BS-1 • SOUNDING BS-1b
Figure 5b

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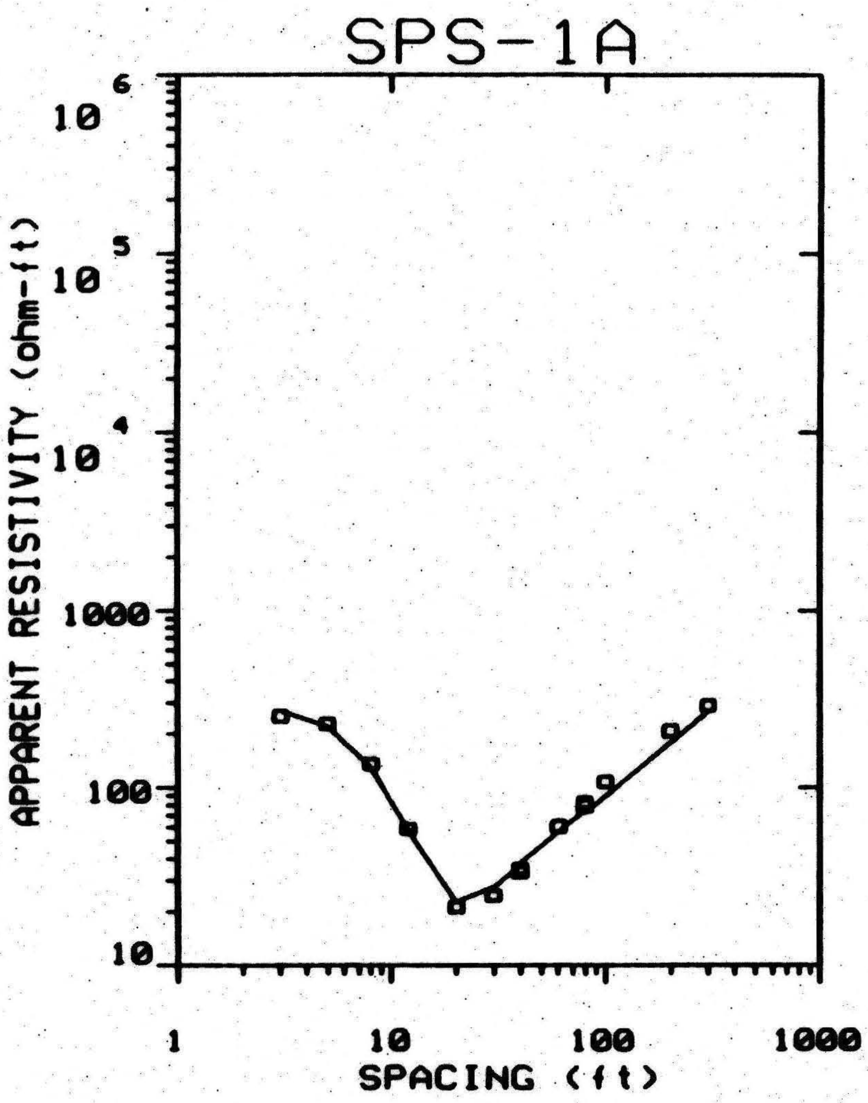

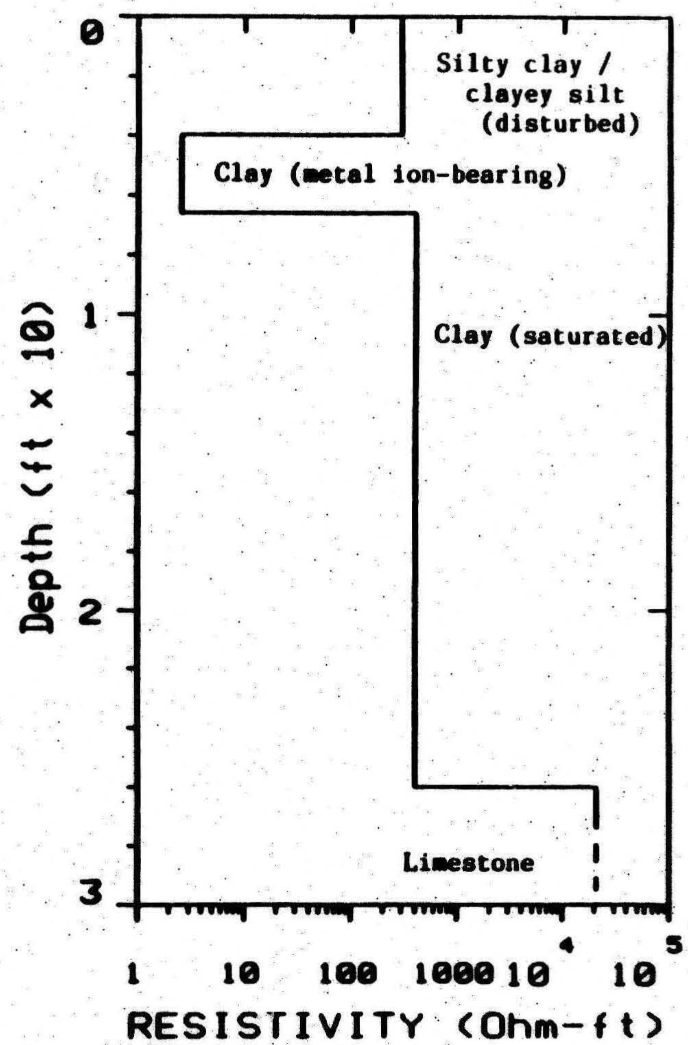

RESISTIVITY INVESTIGATION OF BURIED METAL-BEARING SLUDGE PONDS
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VERTICAL ELECTRICAL SOUNDING
MODEL SPS-1 • SOUNDING SPS-1a

Project No. 90-036 | Figure 6a | February, 1991

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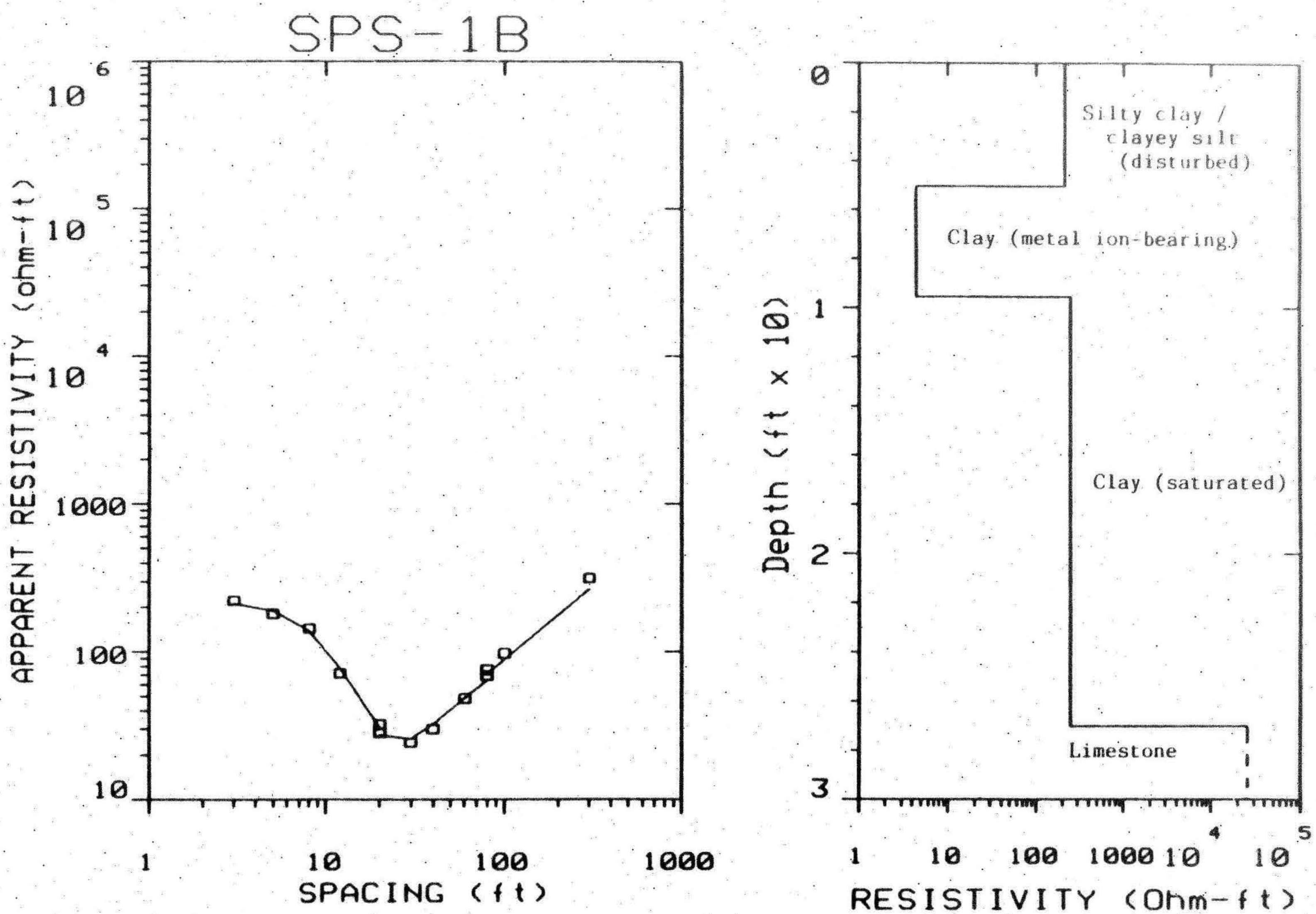

RESISTIVITY INVESTIGATION OF BURIED METAL-BEARING SLUDGE PONDS
Litton ACD, Springfield, Missouri

VERTICAL ELECTRICAL SOUNDING
MODEL SPS-1 • SOUNDING SPS-1b
Figure 6b

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